US009016872B2

(12) **United States Patent**
Aruga

(10) **Patent No.: US 9,016,872 B2**
(45) **Date of Patent: Apr. 28, 2015**

(54) **PROJECTOR AND METHOD FOR PROJECTING IMAGE FROM PROJECTOR**

(71) Applicant: **Seiko Epson Corporation**, Tokyo (JP)

(72) Inventor: **Tadanori Aruga**, Torrance, CA (US)

(73) Assignee: **Seiko Epson Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 142 days.

(21) Appl. No.: **13/747,354**

(22) Filed: **Jan. 22, 2013**

(65) **Prior Publication Data**

US 2013/0194554 A1 Aug. 1, 2013

(30) **Foreign Application Priority Data**

Jan. 27, 2012 (JP) 2012-015046

(51) **Int. Cl.**

G03B 21/14	(2006.01)
G03B 21/26	(2006.01)
H04N 9/74	(2006.01)
H04N 9/31	(2006.01)
G09G 3/00	(2006.01)

(52) **U.S. Cl.**

CPC ***G03B 21/147*** (2013.01); *G03B 21/14* (2013.01); ***H04N 9/3182*** (2013.01); ***H04N 9/3194*** (2013.01); ***G09G 3/002*** (2013.01); *G09G 2310/04* (2013.01); *G09G 2320/0626* (2013.01); *G09G 2360/145* (2013.01)

(58) **Field of Classification Search**

CPC G03B 21/26

USPC 353/97, 28, 69, 70, 121; 348/586, 590, 348/607

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0158425	A1*	7/2006	Andrews et al.	345/156
2008/0106706	A1*	5/2008	Holmgren et al.	353/121

FOREIGN PATENT DOCUMENTS

JP	2000-305481	A	11/2000

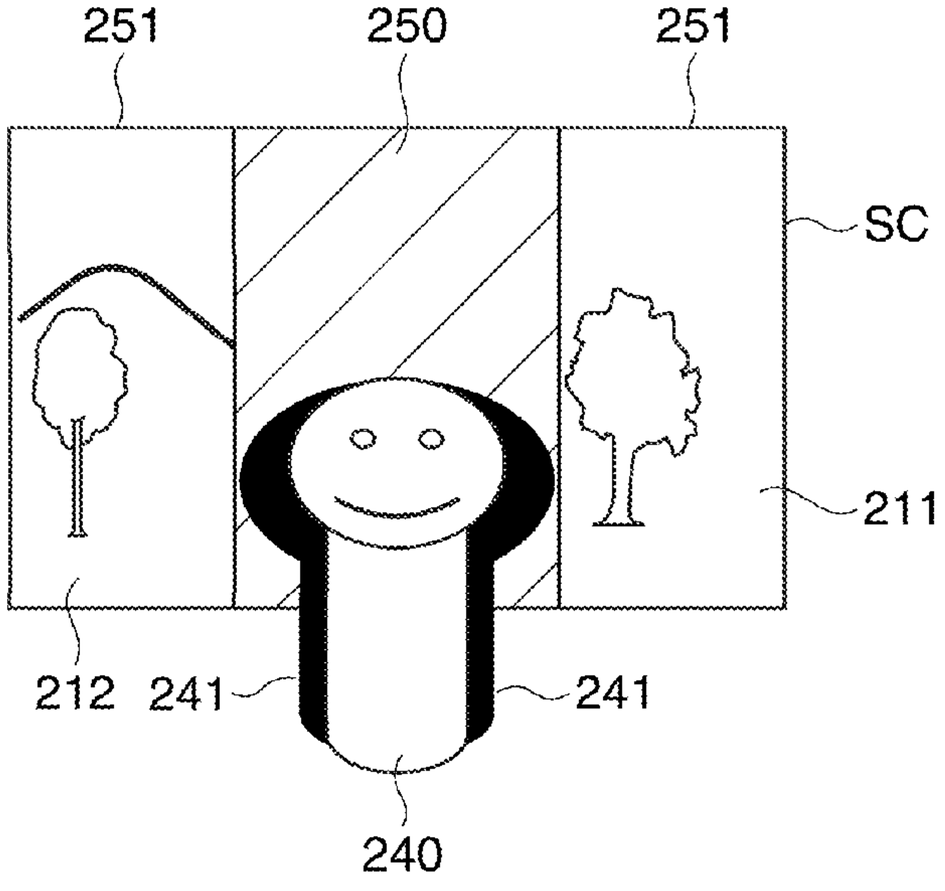
* cited by examiner

Primary Examiner — William C Dowling
Assistant Examiner — Ryan Howard
(74) *Attorney, Agent, or Firm* — ALG Intellectual Property, LLC

(57) **ABSTRACT**

A projector that modulates light emitted from a light source and projects the modulated image light on a projection surface, the projector including: an object detection unit for determining the position of an object that blocks projection of the image light; a distance detection unit for determining the distance to the object; and a projection control unit for determining an avoidance area where the object prevents the image light from reaching the projection surface based on the position of the object determined by the object detection unit and the distance to the object determined by the distance detection unit and projecting the image light in an area other than the avoidance area.

9 Claims, 6 Drawing Sheets



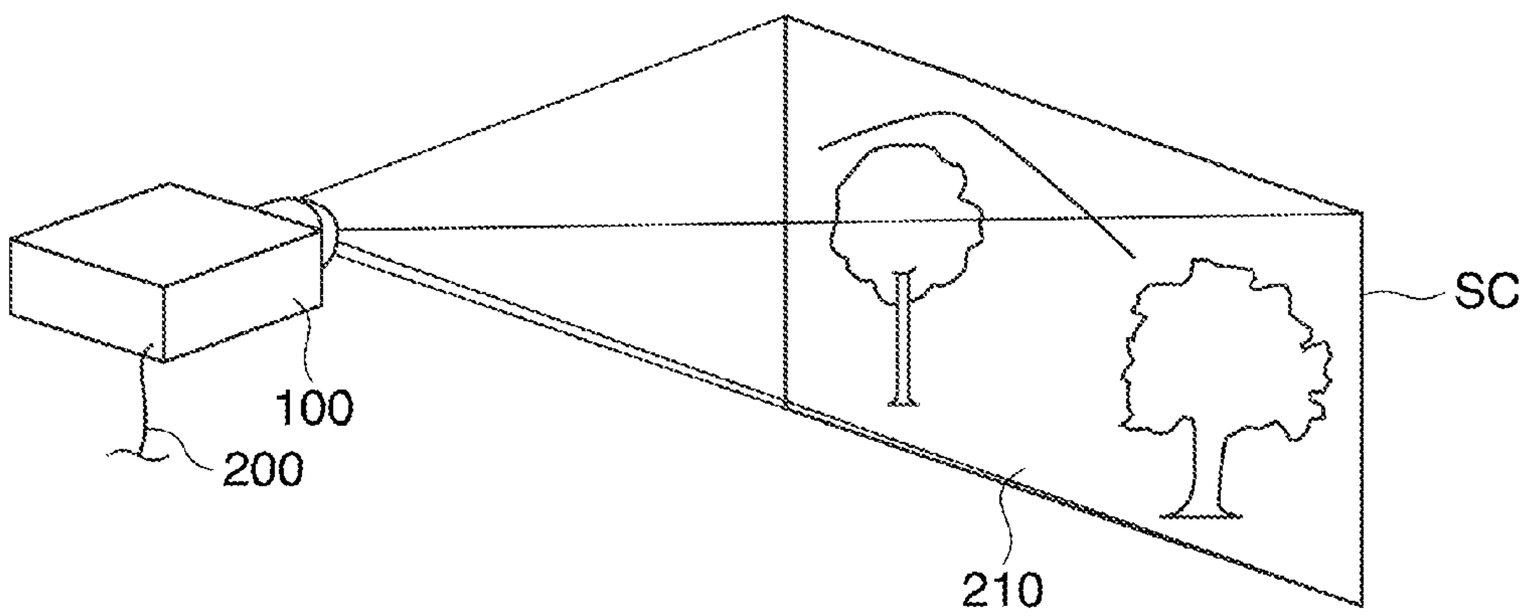


FIG. 1

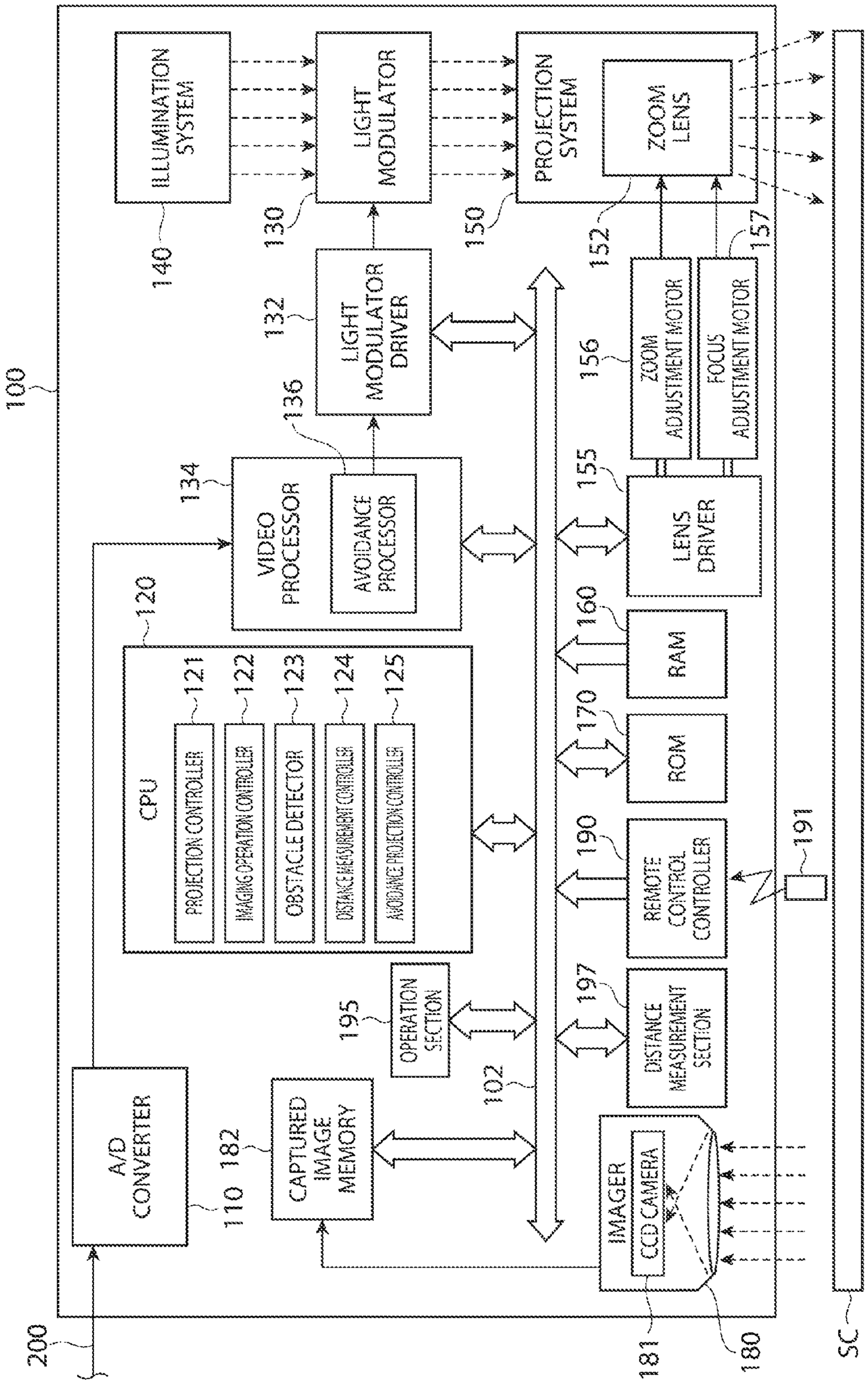

100
ILLUMINATION SYSTEM
140
LIGHT MODULATOR
130
PROJECTION SYSTEM
150
ZOOM LENS
152
157
LIGHT MODULATOR DRIVER
132
VIDEO PROCESSOR
134
AVOIDANCE PROCESSOR
136
ZOOM ADJUSTMENT MOTOR
156
FOCUS ADJUSTMENT MOTOR
158
LENS DRIVER
155
CPU
120
PROJECTION CONTROLLER
121
IMAGING OPERATION CONTROLLER
122
OBSTACLE DETECTOR
123
DISTANCE MEASUREMENT CONTROLLER
124
AVOIDANCE PROJECTION CONTROLLER
125
RAM
160
ROM
170
REMOTE CONTROL CONTROLLER
190
191
OPERATION SECTION
195
DISTANCE MEASUREMENT SECTION
197
A/D CONVERTER
110
CAPTURED IMAGE MEMORY
182
102
IMAGER
CCD CAMERA
181
180
200
SC

FIG. 2

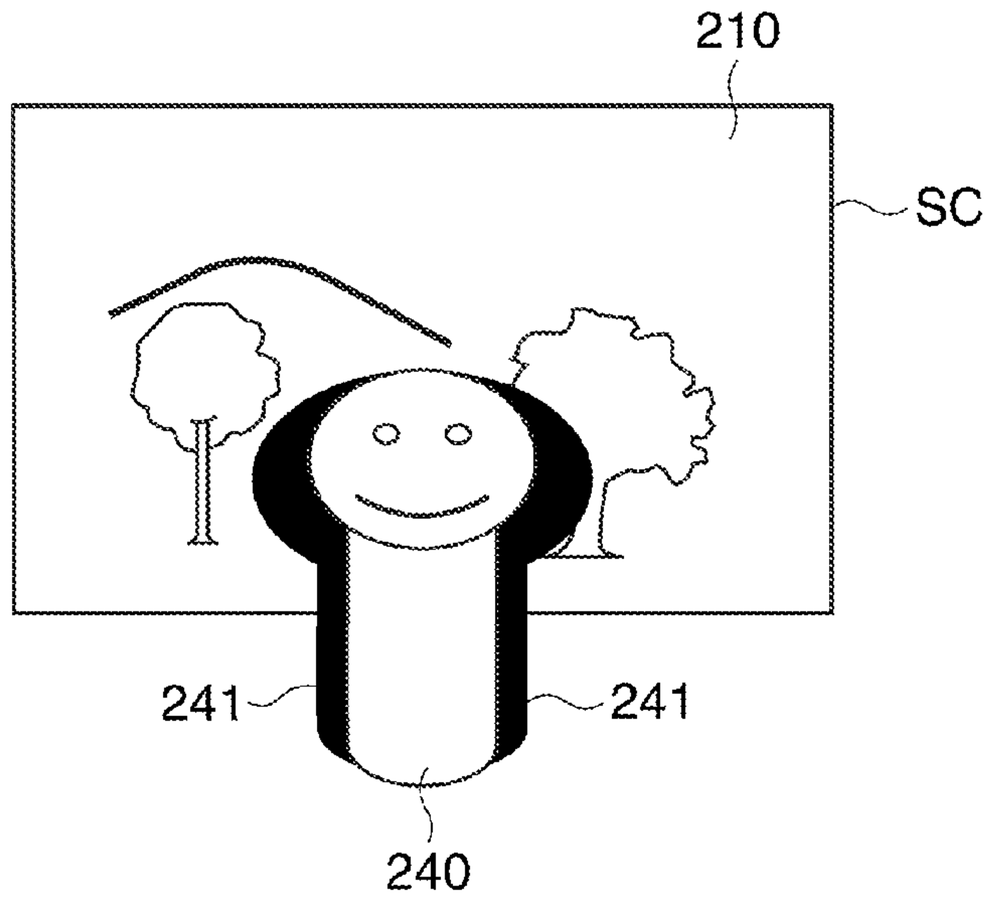


FIG. 3A

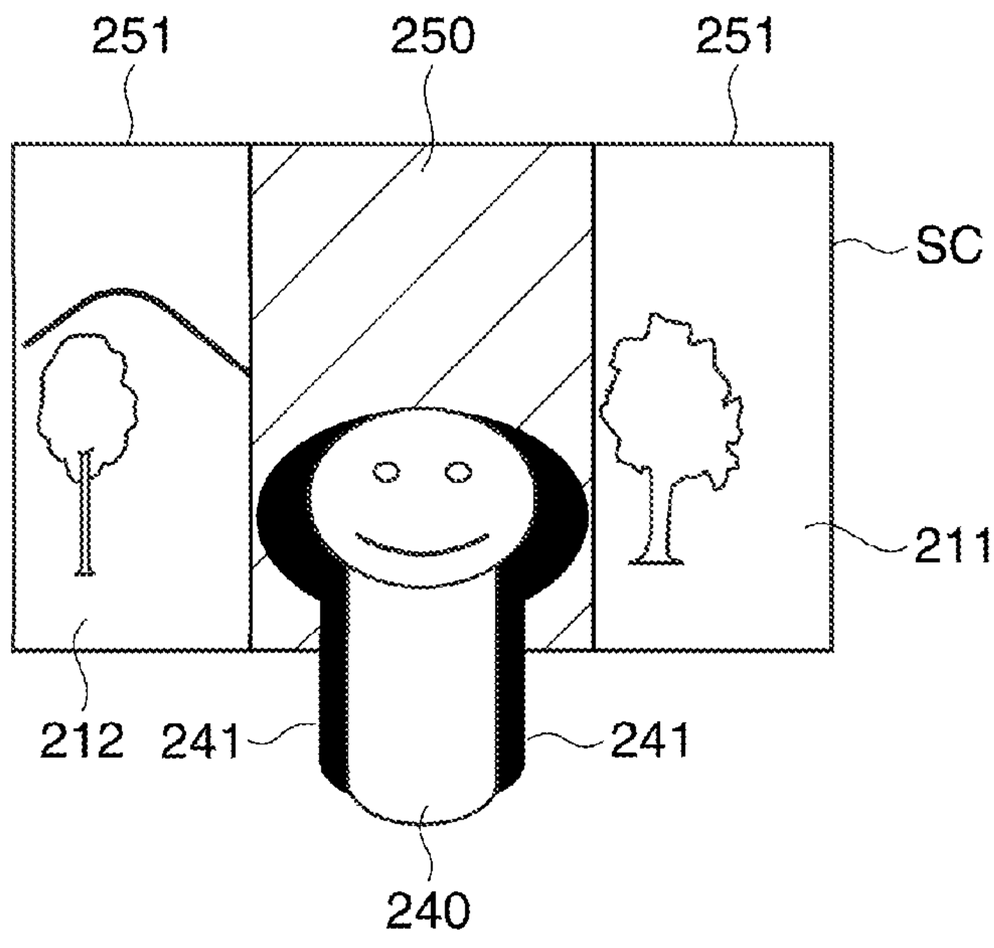


FIG. 3B

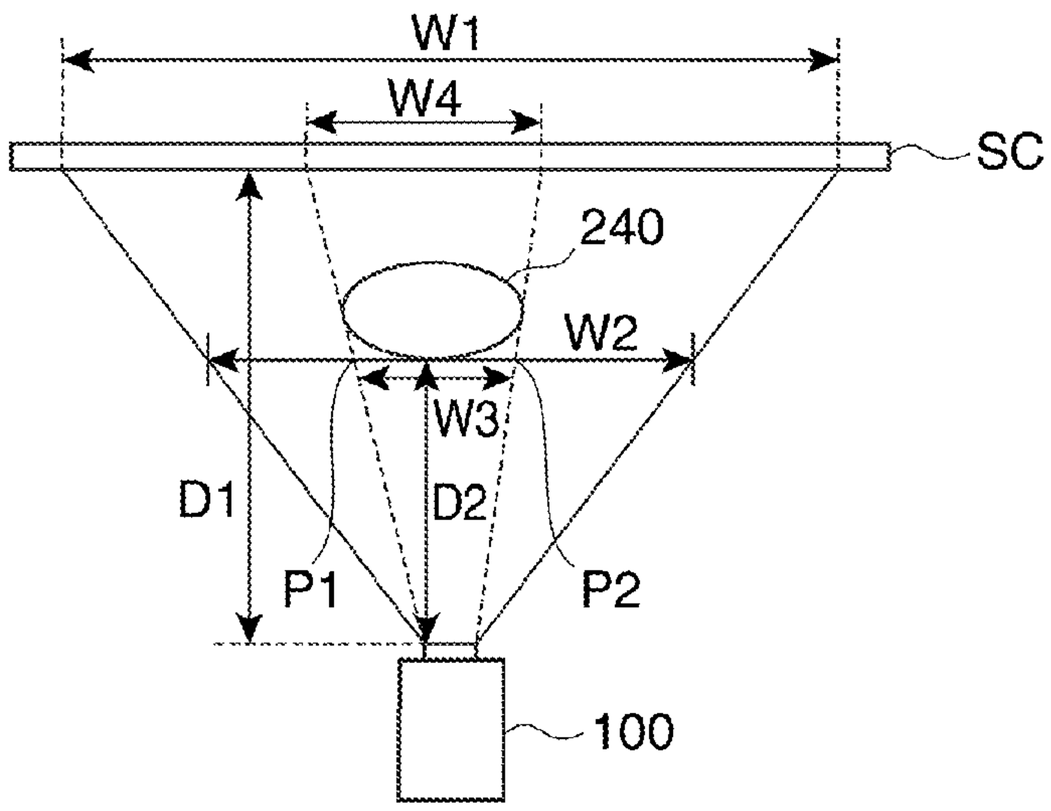


FIG. 4

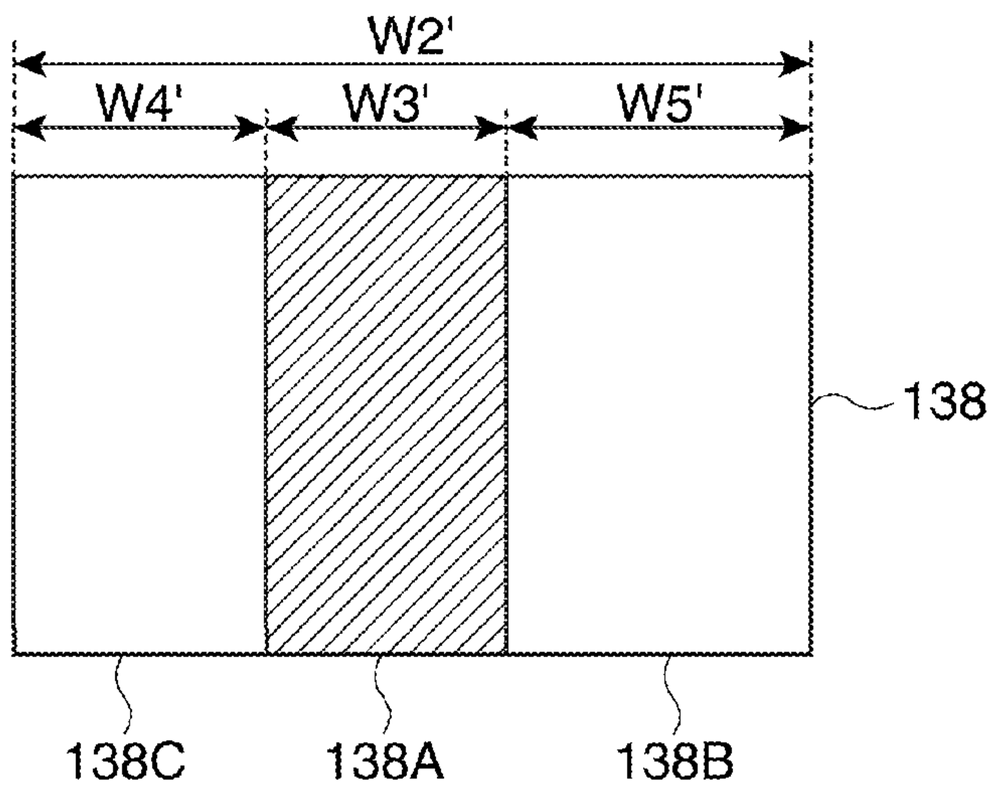


FIG. 5

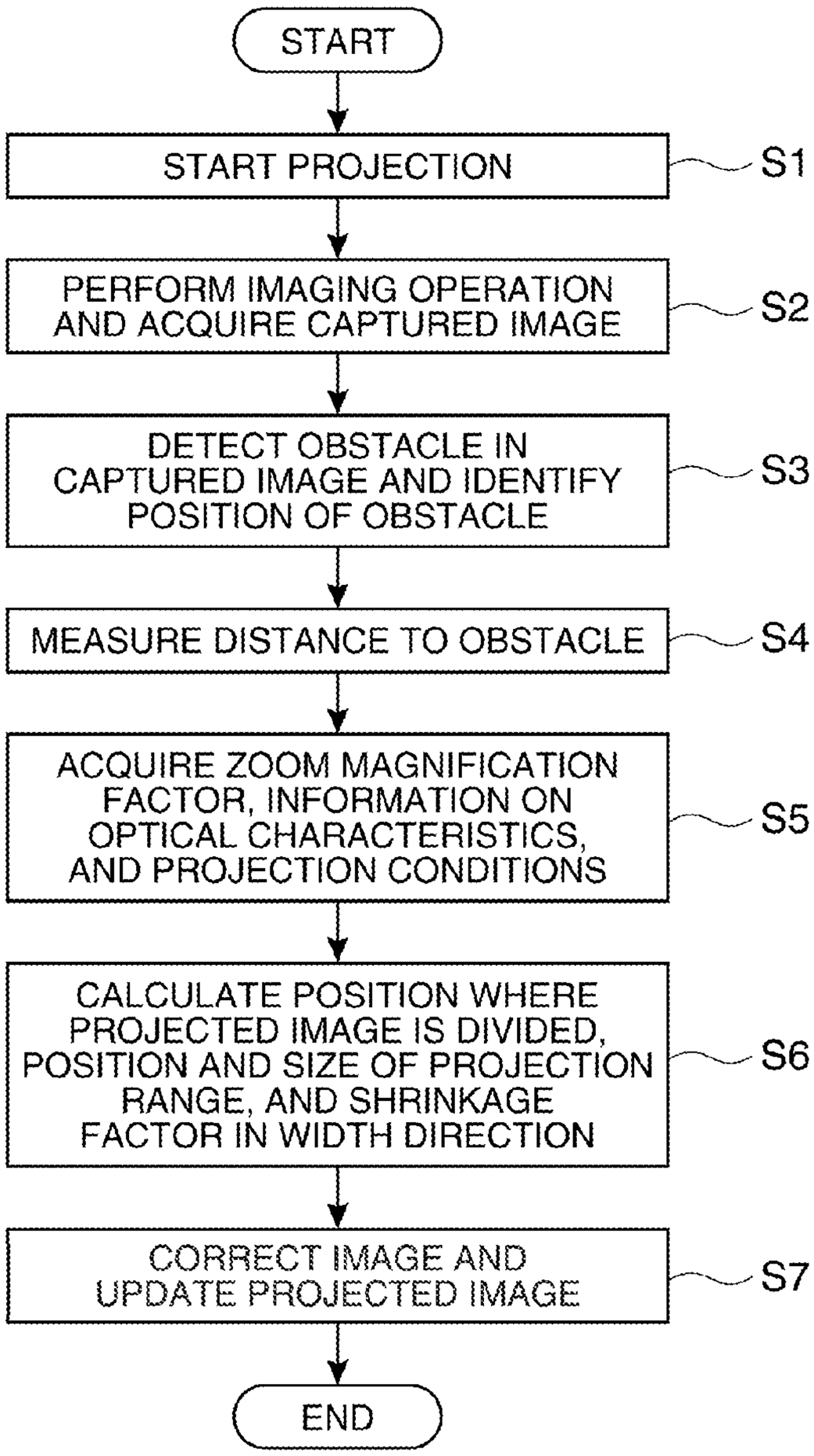

START
START PROJECTION
S1
PERFORM IMAGING OPERATION AND ACQUIRE CAPTURED IMAGE
S2
DETECT OBSTACLE IN CAPTURED IMAGE AND IDENTIFY POSITION OF OBSTACLE
S3
MEASURE DISTANCE TO OBSTACLE
S4
ACQUIRE ZOOM MAGNIFICATION FACTOR, INFORMATION ON OPTICAL CHARACTERISTICS, AND PROJECTION CONDITIONS
S5
CALCULATE POSITION WHERE PROJECTED IMAGE IS DIVIDED, POSITION AND SIZE OF PROJECTION RANGE, AND SHRINKAGE FACTOR IN WIDTH DIRECTION
S6
CORRECT IMAGE AND UPDATE PROJECTED IMAGE
S7
END

FIG. 6

PROJECTOR AND METHOD FOR PROJECTING IMAGE FROM PROJECTOR

CROSS-REFERENCE

The entire disclosure of Japanese Patent Application No. 2012-015046 filed on Jan. 27, 2012, which is hereby incorporated by reference in its entirety.

BACKGROUND

1. Technical Field

The present invention relates to a projector and a method for projecting an image from the projector.

2. Related Art

When a person is present between a projector that is projecting an image on a projection surface and the projection surface, light radiated from the projector directly hits the person, who is dazzled by the light. To address the problem, there is a proposed technology for lowering the luminance of the light in an area where the light overlaps with the person to reduce the degree of dazzle felt by the person.

On the other hand, when the light hits the person in front of the projection surface, the person in front of the projection screen blocks a portion of an image on the projection surface and hence a person who is looking at the image cannot see the portion thereof. The problem also occurs when an object is present in front of the projection screen and blocks the light from the projector as well as in the case where a person is present in front of the projection screen. Such a situation is problematic because part of an image is invisible and information associated therewith is lost.

SUMMARY

An advantage of some aspects of the invention is to allow a person to satisfactorily view an image projected on a projection surface without loss of information even when an object that blocks light projection on the projection surface is present.

An aspect of the invention relates to a projector that modulates light emitted from a light source and projects the modulated image light on a projection surface. The projector includes an object detection unit that determines the position of an object that blocks projection of the image light, a distance detection unit that determines the distance to the object, and a projection control unit that determines an avoidance area where the object prevents the image light from reaching the projection surface based on the position of the object determined by the object detection unit and the distance to the object determined by the distance detection unit and projects the image light in an area other than the avoidance area.

According to the aspect of the invention, the projection is so performed that the area where the object blocks the image light projection is avoided. The projection can therefore be so performed that the projected image itself or information carried by the image are entirely visible without any loss.

Another aspect of the invention relates to the projector described above, wherein the projection control unit further includes a modulation unit that forms an image to be projected and modulates the light emitted from the light source based on the formed image, wherein the projection control unit deforms the entire image formed by the modulation unit in such a way that the deformed image avoids the avoidance area, and the projection control unit projects the image light in an area other than the avoidance area.

According to this aspect of the invention, the area where the object blocks the image light projection can be readily avoided by performing the image processing described above on the image formed by the modulation unit.

Still another aspect of the invention relates to the projector described above, wherein the projection control unit divides the image formed by the modulation unit into a plurality of images and project the image light in areas other than the avoidance area.

According to this aspect of the invention, even when the area where the obstacle blocks the image light projection is located in a primary position of the projection surface, such as in a position exactly in front of the projector, the image light can be projected in an area other than this area in such a way that all information contained in the projected image is visible.

Yet another aspect of the invention relates to the projector described above, wherein the projection control unit shrinks the image formed by the modulation unit to project the image light in an area other than the avoidance area.

According to this aspect of the invention, even when an elongated object (such as a person) extending in the vertical direction of the projection surface blocks the image light projection, for example, the projection can be so performed that the projected image is entirely visible.

Still yet another aspect of the invention relates to the projector described above, which further includes an imaging unit that captures an image of the projection surface, wherein the object detection unit determines the position of an object that blocks projection of the image light based on the image captured by the imaging unit, and the projection control unit determines an avoidance area where the object prevents the image light from reaching the projection surface based on the position of the object in the captured image and the distance to the object determined by the distance detection unit.

According to this aspect of the invention, since the area of the projection surface that is hidden by the object and where the projection is blocked can be accurately identified, the projection can be so performed that any influence of the object that blocks the image light projection can be reliably eliminated and a projected image is entirely visible.

Further another aspect of the invention relates to a method for using a projector that modulates light emitted from a light source and projects the modulated image light on a projection surface. The method includes determining the position of an object that blocks projection of the image light, determining the distance to the object, and determining an avoidance area where the object prevents the image light from reaching the projection surface based on the position of the object and the distance to the object and projecting the image light in an area other than the avoidance area.

According to this aspect of the invention, the projection is so performed that the area where the object blocks the image light projection is avoided. The projection can therefore be so performed that the projected image itself or information carried by the image are entirely visible without any loss.

According to the aspects of the invention, since the projection is so performed that the area where an object blocks the image light projection is avoided, the projection can be so performed that a projected image is entirely visible.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described with reference to the accompanying drawings, wherein like numbers reference like elements.

FIG. **1** is an exterior view showing an example of a projector in use according to an embodiment.

FIG. **2** is a block diagram showing a functional configuration of the projector.

FIGS. **3**A and **3**B are descriptive diagrams showing exemplary projection states. FIG. **3**A shows a normal projection state, and FIG. **3**B shows a projection state after avoidance projection in which projection is performed without interference with an obstacle.

FIG. **4** is a diagrammatic view showing an example of the positional relationship between an obstacle and the projector.

FIG. **5** is a diagrammatic view of a display area of a light modulator.

FIG. **6** is a flowchart showing the operation of the projector.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

An embodiment of the invention will be described below with reference to the drawings.

FIG. **1** is an exterior view showing an example of a projector **100** in use according to an embodiment to which the invention is applied.

In the example shown in FIG. **1**, the projector **100** is installed in front of a screen SC (projection surface) and projects projection light toward the screen SC, and a projected image **210** is focused on the screen SC. The screen SC may simply be a wall surface or any other flat surface or may be attached to the floor, wall, or ceiling of a room.

The projector **100** is installed and a zoom magnification factor, which will be described later, and other parameters associated with the projector **100** are adjusted in such a way that the projected image **210** is focused in a projection area of the screen SC. The projector **100** is connected to an image supply apparatus (not shown) via a cable **200** and projects an image inputted from the image supply apparatus.

FIG. **2** is a block diagram showing an overall configuration of the projector **100** according to the embodiment.

The projector **100** includes a USB interface, a wired or wireless LAN interface, a VGA terminal to which an analog video signal is inputted, a DVI (digital visual interface) to which a digital video signal is inputted, an S video terminal to which a composite video signal in the format of NTSC, PAL, SECAM, and any other standard is inputted, an RCA terminal to which a composite video signal is inputted, and a D terminal to which a component video signal is inputted, and an HDMI® connector that complies with the HDMI standard (any of the components described above is not shown) as an interface to which the image supply apparatus described above is connected and an interface circuit (not shown) that allows signals to be inputted and outputted via any of the terminals and the connectors described above, and the cable **200** is a cable appropriate for any of the interfaces described above. The projector **100** may alternatively be connected to the image supply apparatus via wireless communication.

Examples of the image supply apparatus described above may include a video reproducing apparatus, a DVD reproducing apparatus, a television tuner, a CATV set top box, a video game console and any other image output apparatus, and a personal computer (PC). The projector **100** is capable of not only projecting video images (motion pictures) on the screen SC but also keeping projecting a still image on the screen SC. The projector **100** can alternatively accommodate a storage device and project video images from a video source (not shown) stored in the storage device.

The projector **100** is broadly divided into an optical system that forms an optical image and an image processing system that electrically processes a video signal. The optical system, which functions as a projection section, includes an illumination system **140** (light source), a light modulator **130** (modulation unit), and a projection system **150** (projection unit). The illumination system **140** includes a light source formed, for example, of a xenon lamp, an ultrahigh-pressure mercury lamp, or an LED (light emitting diode). The illumination system **140** may further include a reflector and an auxiliary reflector that guide the light emitted from the light source to the light modulator **130** and a group of lenses (not shown) for enhancing optical characteristics of the projection light, a polarizer, or a light controlling device that is disposed in a position along the path extending to the light modulator **130** and attenuates the light emitted from the light source.

The light modulator **130** is formed, for example, of a transmissive liquid crystal panel, which receives a signal from the image processing system, which will be described later, to form an image. The light modulator **130**, for example, includes three liquid crystal panels corresponding to three primary colors RGB in order to project a color image. The light from the illumination system **140** is separated into three RGB color light fluxes, which are incident on the liquid crystal panels corresponding thereto. The color light fluxes pass through the liquid crystal panels, where the color light fluxes are modulated and then combined by a cross dichroic prism or any other light combining system to form image light, which is then delivered to the projection system **150**.

The light modulator **130** does not necessarily include three transmissive liquid crystal panels but may, for example, include three reflective liquid crystal panels, a combination of a single liquid crystal panel and a color wheel, three digital mirror devices (DMDs), or a combination of a single digital mirror device and a color wheel. When only one liquid crystal panel or DMD is used as the light modulator **130**, a member corresponding to the cross dichroic prism or any other light combining system is not required. Further, any configuration capable of modulating the light emitted from the light source other than a liquid crystal panel or a DMD can be used without any problem.

The projection system **150** includes a zoom lens **152** that magnifies or demagnifies an image to be projected and performs focus adjustment; a zoom adjustment motor **156** that adjusts the zooming factor; and a focus adjustment motor **157** that adjusts focusing. The projection system **150** receives the light modulated by the light modulator **130** and uses the zoom lens **152** to focus a projected image on the screen SC. The zoom lens **152**, in which the positions of lenses therein and other parameters are adjusted by the zoom adjustment motor **156** and the focus adjustment motor **157**, performs zoom adjustment in which an image projected on the screen SC is magnified or demagnified and focus adjustment in which the projected image is exactly brought into focus on the screen SC.

A lens driver **155** drives the zoom adjustment motor **156** and the focus adjustment motor **157** for zoom magnification adjustment and focus adjustment under the control of a CPU **120**.

The image processing system is primarily formed of the CPU **120**, which oversees and controls the entire projector **100**, and a video processor **134** and specifically includes an A/D converter **110**, a light modulator driver **132**, the lens driver **155**, a RAM **160**, a ROM **170** including a distortion adjustment image storage section **171**, an imager **180** including a CCD camera **181**, a captured image memory **182**, a remote control controller **190**, a remote control **191**, and an operation section **195**. The elements that form the image processing system are connected to each other via a bus **102**.

The A/D converter **110** converts an analog input signal inputted from the external image supply apparatus described above via the cable **200** into digital image data and outputs the digital image data to the video processor **134**. The video processor **134** adjusts the digital image data inputted from the A/D converter **110** in terms of brightness, contrast, color density, color tone, and the shape and other display states of an image to be projected and then outputs a video signal that reflects the processing described above to the light modulator driver **132**. The light modulator driver **132** drives the light modulator **130** based on the video signal inputted from the video processor **134** and controls the liquid crystal panels or other devices provided in the light modulator **130** to draw an image. The light which is outputted from the illumination system **140** and with which the light modulator **130** is irradiated is thus modulated, and the modulated light is projected through the projection system **150** on the screen SC. Video images corresponding to the video signal inputted to the A/D converter **110** are thus formed as the projected image **210** (FIG. **1**) on the screen SC.

The video processor **134**, which performs image processing, such as brightness, contrast, and color tone correction described above, also performs avoidance projection when an obstacle is present in front of the screen SC by using an avoidance processor **136**. The avoidance projection, in which video images are projected without interference with the obstacle, will be described later. The video processor **134** can be formed of a general-purpose processor commercially available as a DSP (digital signal processor) or can be formed of a dedicated ASIC.

The CPU **120**, along with the video processor **134**, is responsible for the image processing in the projector **100**. The CPU **120** includes a projection controller **121**, an imaging operation controller **122**, an obstacle detector **123**, a distance measurement controller **124**, and an avoidance projection controller **125**. The components described above are achieved by the CPU **120** that executes a specific program stored in the ROM **170** in advance.

When the projector **100** is turned on and starts image projection, the projection controller **121** controls not only the image projection operation but also execution of the avoidance projection, which will be described later, by using the imaging operation controller **122**, the obstacle detector **123**, the distance measurement controller **124**, and the avoidance projection controller **125**.

The imaging operation controller **122** controls imaging operation of the imager **180**. The projector **100** uses an image captured by the imager **180** in the avoidance projection, which will be described later.

The obstacle detector **123** (object detection unit) detects in the avoidance projection an obstacle contained in the captured image captured under the control of the imaging operation controller **122**. Specifically, the position of the obstacle in the captured image is detected. An obstacle used herein is a person or an object that is located between the screen SC and the projector **100** and blocks the projection. In detail, an obstacle refers to what blocks or attenuates the light projected from the projector **100** toward the screen SC in such a way that an original image focused on the screen SC changes. Even a transparent object that reflects or refracts image light projected from the projector **100** in such away that an image focused on the screen SC changes is an obstacle. The obstacle detector **123** detects an obstacle located in front of the screen SC by comparing a projected image contained in captured image data acquired by the imager **180** with an image being projected under the control of the projection controller **121**.

When the obstacle detector **123** detects an obstacle located in front of the screen SC, the distance measurement controller **124** instructs a distance measurement section **197** to measure the distance to the obstacle. The distance measurement section **197** is a sensor that uses laser light or infrared light to measure the distance to a subject and is oriented in the projection direction in which the projection system **150** projects image light. The distance measurement section **197** measures the distance to an object (including a person) present in the projection direction of the projection system **150** and outputs the measurement to the CPU **120** under the control of the distance measurement controller **124**. The distance measurement controller **124** functions not only as the distance measurement section **197** but also as a distance detection unit.

When the obstacle detector **123** detects an obstacle, the avoidance projection controller **125** controls the avoidance projection, which is projection without interference with the obstacle. The avoidance projection is a process of identifying an area on the screen SC that is hidden by an obstacle detected by the obstacle detector **123** based on the position of the obstacle, the distance to the obstacle, and the projection distance to the screen SC and performing projection in an area other than the identified area. Specifically, the avoidance projection controller **125** changes an image formed in the light modulator **130** in such a way that the image is not projected in the area hidden by the obstacle but is projected only in the remaining area. To this end, the avoidance processor **136** provided in the video processor **134** corrects the image under the control of the avoidance projection controller **125**. The avoidance projection controller **125**, along with the avoidance processor **136**, functions as projection control unit. The avoidance projection will be described later in detail.

The RAM **160** provides a work area that temporarily stores programs executed by the CPU **120** and data used by the CPU **120**. The video processor **134** has a work area as a built-in RAM necessary when the video processor **134** itself adjusts states of a displayed image and carries out other processes.

The ROM **170** stores, for example, programs executed by the CPU **120** to provide the processing components described above and data associated with the programs. The ROM **170** also stores adjustment image data to be projected on the screen SC in trapezoidal distortion correction, which will be described later, in the adjustment image storage section **171**.

The operation section **195** is disposed in the body of the projector **100** and has switches operated by a user and a variety of other operation parts and indicator lamps. Under the control of the CPU **120**, the indicator lamps on the operation section **195** go on or off as appropriate in accordance with the operation and settings of the projector **100**, and the operation section **195** outputs an operation signal in response to operation made through any of the operation parts. The remote control controller **190** receives a wireless signal transmitted from the remote control **191** external to the projector **100**. The remote control **191** has operation parts (not shown) operated by the user and transmits an operation signal according to operation made through any of the operation parts in the form of infrared signal or wireless signal using electric radiation of a predetermined frequency. The remote control controller **190**, which includes a light receiver (not shown) that receives the infrared signal or a reception circuit (not shown) that receives the wireless signal, receives a signal transmitted from the remote control **191**, analyzes the received signal, produces a signal representing the user's operation, and outputs the signal to the CPU **120**.

The imager **180** (imaging unit) includes the CCD camera **181** using a CCD, which is a known image sensor. The imager **180** is disposed in the front surface of the projector **100**, that

is, in a position where the CCD camera **181** can perform imaging in the direction in which the projection system **150** projects video images toward the screen SC. The direction and viewing angle of the CCD camera **181** in the imager **180** are so set that an entire projected image projected on the screen SC located at a recommended projection distance falls at least within the image capturing range of the CCD camera **181**.

The imager **180** performs imaging under the control of the imaging operation controller **122**. The imager **180** sets the shutter speed in accordance with control data inputted from the imaging operation controller **122** and instructs the CCD camera **181** to perform imaging at the thus set shutter speed at the timing specified by the imaging operation controller **122**.

The CCD camera **181** includes not only a CCD but also a single-focus lens that forms video images on the CCD, an auto-iris mechanism that adjusts the amount of light incident on the CCD and other mechanisms, and a control circuit that reads a video signal from the CCD. The auto-iris mechanism receives from the control circuit a signal corresponding to accumulated brightness of video images from the CCD camera **181** and automatically adjusts an iris (diaphragm) provided in the vicinity of the single-focus lens in such a way that the accumulated brightness falls within a predetermined range.

An image having undergone the brightness adjustment using the auto-iris mechanism is outputted from the imager **180** to the captured image memory **182** and repeatedly written to a predetermined area of the captured image memory **182**. Whenever the writing operation of an image corresponding to a single screen is completed, the captured image memory **182** successively reverses a flag associated with the predetermined area. Referring to the flag, the imaging operation controller **122** can recognize whether or not the imager **180** has completed imaging operation. The imaging operation controller **122** accesses the captured image memory **182** while referring to the flag and acquires a necessary captured image.

FIGS. **3**A and **3**B are descriptive diagrams showing exemplary projection states. FIG. **3**A shows a normal projection state, and FIG. **3**B shows a projection state after the avoidance projection, in which projection is performed without interference with an obstacle.

When a person **240** is present as an obstacle in front of the screen SC, the person **240** hides a large portion of the projected image **210** focused on the screen SC, as shown in FIG. **3**A. The reason for this is that projection performed by the projector **100** disposed in front of the screen SC as described with reference to FIG. **1** produces a shadow **241** of the person **240** located in front of the screen SC on the screen SC.

To address the problem, having detected that the person **240** is present, the projector **100** performs the avoidance projection. In the avoidance projection, the area of the projected image **210** that is hidden by the presence of the person **240** in consideration of the influence of the shadow **241** of the person **240** is determined as an avoidance area **250**. The projector **100** then projects an image in an area **251** that does not contain the avoidance area **250**. When the area **251** is smaller than the projected image **210**, which is an original image to be projected on the screen SC, the image is demagnified (shrunk) and projected in the area **251**. When the avoidance area **250** divides a projectable area of the screen SC into a plurality of areas, the projected image **210** is divided before projected, as shown in FIG. **3**B.

Although the avoidance area **250** is arbitrarily shaped, the projector **100** according to the present embodiment forms a rectangular avoidance area **250** extending in the vertical direction across the screen SC, as shown in FIG. **3**B. In this case, although the person **240** will not hide at least an upper portion of the avoidance area **250**, the following advantages are provided as compared with a case where a minimum area hidden by the person **240** and the shadow **241** is set to be the avoidance area **250**: no computation in the height direction is required; better visibility is provided because the projected image **210** is shrunk only in the horizontal (transverse) direction; and so on. In the present embodiment, the size of the avoidance area **250** in the height direction is therefore set to be equal to the size of the screen SC (or projectable area of screen SC). When the configuration of the projector **100** allows computation in the height direction to be performed, an avoidance area **250** that is not uniformly shaped in the vertical direction of the screen SC may be set, and an image may be projected in an area other than the avoidance area **250**.

FIG. **4** is a diagrammatic view showing an example of the positional relationship between an obstacle and the projector **100**. The avoidance projection will be described in detail with reference to FIG. **4**.

In the avoidance projection, the avoidance projection controller **125** calculates the projection distance D**1** from the projector **100** to the screen SC and the size W**1** of the projection range (projected image) on the screen SC based on the zoom magnification factor of the zoom lens **152** and information on optical characteristics specific to the projector **100**.

The avoidance projection controller **125** further instructs the distance measurement controller **124** to measure the distance D**2** from the projector **100** to the person **240**, who is an obstacle, and acquires the measurement from the distance measurement controller **124**.

The avoidance projection controller **125** uses the function of the obstacle detector **123** to determine the positions P**1** and P**2** of both ends of an image of the person **240** in a captured image captured by the imager **180**. The avoidance projection controller **125** thus determines the size W**3** between the positions P**1** and P**2** of the two ends.

The avoidance projection controller **125** then determines the size W**4** of the avoidance area and the position thereof on the screen SC based on the size W**1** of the projection range, the projection distance D**1**, the positions P**1** and P**2** of the two ends, and the size W**3**. The avoidance projection controller **125** further determines the size W**2** of the image light projection range in the position of the person **240**.

The avoidance projection controller **125** subsequently controls the avoidance processor **136** to deform an image to be formed in an image drawing area of the light modulator **130**.

FIG. **5** is a diagrammatic view of an image formation area **138** of the light modulator **130**.

The image formation area **138** shown in FIG. **5** is an area where an image is formed by pixels arranged in a matrix in a liquid crystal panel, a DMD, or any other device provided in the light modulator **130**, and the image formed in the image formation area **138** modulates the light outputted from the illumination system **140**.

The avoidance projection controller **125** sets an avoidance area **138**A in the image formation area **138** based on the size W**2** of the image light projection range in the position of the person **240**, who is an obstacle, and the size W**3** between the positions P**1** and P**2** of the two ends of the person **240**. Portions of the image formation area **138** other than the avoidance area **138**A form image drawing areas **138**B and **138**C where images are formed. Since the person **240** divides the projectable area of the screen SC into two in the present embodiment, there are two image drawing areas **138**B and **138**C. On the other hand, there is one image drawing area, for example, when an obstacle is positioned at an end of the

screen SC. The position of the avoidance area **138**A is determined based on the positions P**1** and P**2** of the two ends of the person **240**, and the width of the avoidance area **138**A is determined by the ratio between the size W**2** and the size W**3**. That is, the ratio between the size W**3**' of the avoidance area **138**A and the size W**2**' of the image formation area **138** is equal to the ratio between the size W**3** and the size W**2**.

The avoidance projection controller **125** determines whether or not image shrinkage is required and the shrinkage factor based on the sizes W**4**' and W**5**' of the image drawing areas **138**B and **138**C and the size W**2**' of the entire image formation area **138**. The image shrinkage factor is determined, for example, by (W**4**'+W**5**')+W**2**'.

The avoidance projection controller **125** then controls the avoidance processor **136** to divide an image inputted from the A/D converter **110** based on the position of the avoidance area **138**A and shrinks the divided images in the horizontal direction based on the shrinkage factor described above to produce images to be disposed in the image drawing areas **138**B and **138**C. When the light modulator driver **132** draws the shrunk images in the light modulator **130**, projected images **211** and **212** (FIG. **3**B) that avoid the person **240** are projected on the screen SC.

When the person **240** is positioned at an end of the screen SC as described above or positioned in a predetermined range that can be considered to be an end of the screen SC, the avoidance area **138**A is set at one end of the image formation area **138**, and one image drawing area **138**B adjacent to the avoidance area **138**A is set. In this case, the avoidance projection controller **125** instructs the avoidance processor **136** not to divide an image but to simply shrink and locate the image.

The process of shrinking an image refers, for example, to a process of resizing the image in order to draw the image with a smaller number of pixels.

FIG. **6** is a flowchart showing the operation of the projector **100** and shows the avoidance projection.

After the projector **100** starts projection (step S**1**) and projects an image on the screen SC, and the user operates the operation section **195** or the remote control **191** to instruct the projector **100** to perform the avoidance projection, the projector **100** starts the avoidance projection.

In the avoidance projection, the CPU **120** in the projector **100** controls the imager **180** based on the function of the imaging operation controller **122** to perform imaging operation and acquires captured image data from the captured image memory **182** (step S**2**).

The CPU **120** subsequently detects an obstacle contained in the captured image based on the function of the obstacle detector **123** and, when an obstacle is detected, identifies the position of the obstacle in the captured image (step S**3**).

The CPU **120** then controls the distance measurement section **197** based on the function of the distance measurement controller **124** to measure the distance to the obstacle (step S**4**).

The CPU **120** further uses the function of the avoidance projection controller **125** to acquire the zoom magnification factor of the projection system **150**, the information on optical characteristics of the projector **100**, and the projection conditions (step S**5**) and determine what attributes of an image to be projected are corrected in the correction process based on the information described above (step S**6**). That is, when the avoidance processor **136** divides an image inputted from the A/D converter **110** as described above, the avoidance projection controller **125** determines the position where the image is divided. Further, when the image needs to be shrunk in the width direction, the avoidance projection controller **125** determines the shrinkage factor and further determines the position and size of a projectable area that avoids the obstacle. The CPU **120** then performs image drawing in the image formation area **138** as shown in FIG. **5**, updates the projected image on the screen SC (step S**7**), and completes the procedure.

After the procedure shown in FIG. **6** is completed and when the obstacle is not appropriately avoided, the user operates the remote control **191** or the operation section **195** to instruct the projector **100** to perform the avoidance projection again.

As described above, according to the embodiment to which the invention is applied, the projector **100**, which modulates the light outputted from the illumination system **140** and projects the modulated image light on the screen SC, includes the obstacle detector **123**, which determines the position of an obstacle that blocks image light projection, the distance measurement controller **124**, which determines the distance to the obstacle, and the avoidance projection controller **125**, which determines an avoidance area where the obstacle prevents the image light from reaching the screen SC based on the position of the obstacle determined by the obstacle detector **123** and the distance to the obstacle determined by the distance measurement controller **124** and projects the image light in an area other than the avoidance area. The projection can therefore be so performed that the projected image itself or information carried by the image are entirely visible without any loss.

Since projection can be performed without any image truncation even when a person or an object that blocks projection light (image light) is present in the vicinity of the screen SC, no situation in which characters or any other objects contained in an image are not visible will occur. A person who is looking at the screen SC can therefore grasp all information contained in the projected image.

Therefore, for example, even when a presenter who uses the projector **100** stands in front of the screen SC, the body of the presenter will not block image projection. In this case, the presenter can make presentation without being careful about the position where the presenter is standing, whereby it is expected that the convenience of the presenter is improved.

Further, since an object that can be an obstacle can be present between the screen SC and the projector **100**, the degree of freedom in installing the projector **100** increases.

Further, since the projector **100** includes the light modulator **130**, which forms an image to be projected and uses the formed image to modulate the light outputted from the illumination system **140**, and the avoidance projection controller **125** deforms the entire image formed by the light modulator **130** in such a way that the deformed image avoids the avoidance area and projects the image light in an area other than the avoidance area, the area where the obstacle blocks image light projection can be readily avoided by performing the image processing described above on the image formed by the light modulator **130**.

Further, the avoidance projection controller **125** divides the image formed by the light modulator **130** into a plurality of images and projects the divided images in areas on both sides of the avoidance area. Therefore, even when the area where the obstacle blocks the image light projection is located in a primary position of the screen SC, such as in a position exactly in front of the projector **100**, the image light can be projected in an area other than this area in such a way that all information contained in the projected image is visible.

Further, the avoidance projection controller **125** shrinks the image formed by the light modulator **130** in the horizontal direction. For example, when a person is standing in front of the screen SC as shown in FIG. **3**B, the image light projection

is blocked in the vertical direction of the screen SC. Even when an elongated obstacle extending in the vertical direction of the screen SC is present as described above, setting an avoidance area extending in the vertical direction of the screen SC and projecting an image not in the avoidance area but in areas on both sides thereof allows the projected image to be entirely visible.

Further, the projector **100** includes the imager **180**, which captures an image of the screen SC, the obstacle detector **123** determines the position of an obstacle based on the image captured by the imager **180**, and the avoidance projection controller **125** determines an avoidance area where the obstacle prevents the image light from reaching the screen SC based on the position of the obstacle in the captured image and the distance to the obstacle determined by the distance measurement controller **124**. The area of the screen SC that is hidden by the obstacle and where the projection is blocked can therefore be accurately identified. As a result, the projection can be so performed that any influence of the obstacle can be reliably eliminated and a projected image is entirely visible.

The embodiment described above is only an example of a specific aspect to which the invention is applied and does not intend to limit the scope of the invention, and the invention is applicable to an aspect different from the above embodiment. For example, the above embodiment, in which no trapezoidal distortion correction is made, has been described with reference to the case shown in FIG. **5** where the entire image formation area **138** of the light modulator **130** is used to project an image to be projected, but the invention is not limited to the embodiment described above. The avoidance projection can alternatively be performed after trapezoidal distortion correction is made. In this case, the procedure described above can be carried out in the same manner except that in a trapezoidal distortion correction process, the avoidance areas **138**A, and the image drawing areas **138**B and **138**C are formed in a trapezoidal image drawable area formed in the image formation area **138**.

Further, the above embodiment has been described with reference to the case where the projector **100** installed in front of the screen SC projects an image forward, but the invention is not limited thereto. The invention is also applicable to a configuration in which the screen SC is formed of a transmissive screen and the projector **100** projects an image from the rear side of the screen SC. In this case, the projection can be so performed that an obstacle present between the projector **100** and the screen SC, that is, on the rear side of the screen SC is avoided.

Further, the above embodiment has been described with reference to the configuration in which the imager **180** includes the CCD camera **181** that accommodates a CCD image sensor, but the invention is not limited thereto. The image sensor in the imager **180** may be a CMOS sensor.

Further, a control program, setting values, and other data stored in the ROM **170** in the above embodiment can alternatively be stored in a mobile recording medium, or the projector **100** can alternatively download the program, setting values, and data from another apparatus connected the projector **100** via a communication network.

Further, each of the functional components of the projector **100** shown in FIG. **2** shows a functional configuration and is not necessarily implemented in a specific manner. That is, hardware corresponding to each of the functional components is not necessarily implemented, but it is, of course, possible for a single processor to execute a program to achieve the functions of the plurality of functional components. Further, part of the functions achieved by software in the above embodiment may be achieved by hardware, or part of the functions achieved by hardware in the above embodiment may be achieved by software. In addition, the specific detailed configurations of the projector **100** can be arbitrarily changed to the extent that the change does not depart from the substance of the invention.

What is claimed is:

1. A projector that modulates light emitted from a light source and projects the modulated image light on a projection surface, the projector comprising:

an object detection unit for determining a position of an object that blocks projection of the image light;

a distance detection unit for determining a distance to the object;

a projection control unit for determining an avoidance area where the object prevents the image light from reaching the projection surface based on the position of the object determined by the object detection unit and the distance to the object determined by the distance detection unit and projecting the image light in an area other than the avoidance area; and

a modulation unit for forming an image to be projected and modulating the light emitted from the light source based on the formed image,

wherein the projection control unit deforms the entire image formed by the modulation unit in such a way that the deformed image avoids the avoidance area, and the projection control unit projects the image light in an area other than the avoidance area.

2. The projector according to claim **1**,

wherein the projection control unit divides the image formed by the modulation unit into a plurality of images and projects the image light in areas other than the avoidance area.

3. The projector according to claim **1**,

wherein the projection control unit shrinks the image formed by the modulation unit to project the image light in an area other than the avoidance area.

4. The projector according to claim **1**,

further comprising an imaging unit for capturing an image of the projection surface,

wherein the object detection unit determines the position of the object that blocks the projection of the image light based on the image captured by the imaging unit, and

the projection control unit determines the avoidance area where the object prevents the image light from reaching the projection surface based on the position of the object in the captured image and the distance to the object determined by the distance detection unit.

5. A method for projecting an image from a projector that modulates light emitted from a light source and projects the modulated image light on a projection surface, the method comprising:

determining a position of an object that blocks projection of the image light;

determining a distance to the object;

determining an avoidance area where the object prevents the image light from reaching the projection surface based on the position of the object and the distance to the object;

forming an image to be projected and modulating the light emitted from the light source based on the formed image; and

projecting the image light in an area other than the avoidance area,

wherein the forming step deforms the entire image in such a way that the deformed image avoids the avoidance

area, and the projecting step projects the image light in the area other than the avoidance area.

6. The method according to claim **5**,

wherein the forming step divides the image into a plurality of images and the projecting step projects the image light in areas other than the avoidance area.

7. The method according to claim **5**,

wherein the forming step shrinks the image to project the image light in the area other than the avoidance area.

8. The method according to claim **5**, further comprising:

capturing an image of the projection surface,

wherein the determining step determines the position of the object that blocks the projection of the image light based on the captured image, and

the determining step determines the avoidance area where the object prevents the image light from reaching the projection surface based on the position of the object in the captured image and the distance to the object.

9. A projector that modulates light emitted from a light source and projects the modulated image light on a projection surface, the projector comprising:

an object detection unit for determining a position of an object that blocks projection of the image light;

a distance detection unit for determining a distance to the object;

a projection control unit for determining an avoidance area where the object prevents the image light from reaching the projection surface based on the position of the object determined by the object detection unit and the distance to the object determined by the distance detection unit and projecting the image light in an area other than the avoidance area; and

a modulation unit for forming an image to be projected and modulating the light emitted from the light source based on the formed image,

wherein the projection control unit shrinks the image formed by the modulation unit to project the image light in the area other than the avoidance area.

* * * * *